



**DEVELOPMENT OF ADAPTIVE FUZZY LOGIC
CONTROLLER FOR SATELLITE ATTITUDE
CONTROL SYSTEM**

by

FATIMATUL ANIS BT BAKRI

(1030610514)

A thesis submitted in fulfillment of the requirements for the degree of
Master of Science (Mechatronic Engineering)

**School of Mechatronic Engineering
UNIVERSITI MALAYSIA PERLIS**

2014

UNIVERSITI MALAYSIA PERLIS

DECLARATION OF THESIS

Author's full name : FATIMATUL ANIS BT BAKRI
Date of birth : 20TH JANUARY 1985
Title : DEVELOPMENT OF ADAPTIVE FUZZY LOGIC CONTROLLER FOR
SATELLITE ATTITUDE CONTROL SYSTEM
Academic Session : 2011 - 2014

I hereby declare that the thesis becomes the property of Universiti Malaysia Perlis (UniMAP) and to be placed at the library of UniMAP. This thesis is classified as :

- CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*
- RESTRICTED** (Contains restricted information as specified by the organization where research was done)*
- OPEN ACCESS** I agree that my thesis is to be made immediately available as hard copy or on-line open access (full text)

I, the author, give permission to the UniMAP to reproduce this thesis in whole or in part for the purpose of research or academic exchange only (except during a period of _____ years, if so requested above).

Certified by:


SIGNATURE


SIGNATURE OF SUPERVISOR

850120025482
(NEW IC NO. / PASSPORT NO.)

PROF. DR. MOHD YUSOFF MASHOR
NAME OF SUPERVISOR

NOTES : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. First and foremost, I would like to thank Allah s.w.t for giving me the strengths and His blessing in completing this thesis. Alhamdulillah, all praises to Allah. Special appreciation goes to my supervisor, Prof. Dr. Mohd Yusoff Mashor for providing me the knowledge and whom never failed and stops giving me support from the beginning until the end which makes this research possible to be completed. His guidance and motivations always keep me focused on the objective of the research and choosing the right way in accomplishing it.

I would also like to convey my gratitude to the Ministry of Higher Education (MOHE) and University Technology Mara (UiTM), for the scholarship as well as Astronautic Technology (M) Sdn. Bhd. (ATSB) for providing the information and constructive guidance during the research study. I would like to express my deepest gratitude to my beloved parents, Bakri Rasyid and Nur Hayati Daud, and the rest of my family for the prayer, love, motivation and encouragement that inspire me to strive harder for achieving the dreams.

Not forgetting a big appreciation towards InnoSAT team members especially Siti Maryam, Norhayati and Fadhilah for all the support in terms of knowledge, advice and streaming motivation during this period which helps to keep my faith solid as ever. Last but not least, I would like to thank my friends, especially to Nadiatun, Aimi, Sara, Tasya and everyone that involves in this research directly and indirectly. Your help and encouragement really means to me. Thank you very much.

TABLE OF CONTENTS

	PAGE
THESIS DECLARATION	i
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iv
LIST OF TABLES	x
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xx
LIST OF SYMBOLS	xxiv
ABSTRAK	xxix
ABSTRACT	xxx
CHAPTER 1 INTRODUCTION	
1.1 Introduction	1
1.2 Problem Statement	3
1.3 Objectives of Research	4
1.4 Scope of Research	4
1.5 Thesis Outline	6
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	8
2.2 Small Satellite	9
2.2.1 CubeSAT	10

2.2.2	InnoSAT Project	11
2.3	Attitude Control System	13
2.4	Techniques of Satellite Attitude Control	17
2.4.1	Spin stabilization Control	17
2.4.2	Three-Axes Stabilization	19
2.4.3	Gravity Gradient Stabilization	20
2.5	Fuzzy Logic Controller	21
2.5.1	Basic structure of Fuzzy Logic Controller	23
2.5.2	Design Issue of Fuzzy Logic Controller	24
2.5.3	Different Approach of Fuzzy Logic Controller	28
2.6	Intelligent Adaptive Fuzzy Logic Controller	30
2.7	Previous Works on Satellite Attitude Control	33
2.8	Summary	37
CHAPTER 3	ADAPTIVE FUZZY LOGIC CONTROLLER	
3.1	Introduction	39
3.2	Model Reference Adaptive Control Scheme	41
3.3	Fuzzy PID Controller Structure	44
3.3.1	Direct Action Type	46
3.3.1.1	Double Input	46
3.3.1.2	Triple Input	54
3.3.2	Hybrid Type	57
3.3.2.1	Fuzzy PI + Fuzzy PD	57
3.3.2.2	Parallel Fuzzy P + Fuzzy I + Fuzzy D	59

3.4	Adaptation Mechanism	61
3.4.1	Proportional, Integral and Derivative (PID) Error	61
3.4.2	Weighted Recursive Least Square (WRLS) Algorithm	62
3.5	Three Axes InnoSAT System with Cross Coupling Effect	65
3.6	Y-Thompson Spin Rate Data	66
3.7	Summary	69

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1	Introduction	71
4.2	Simulation Result for AFLC based on Direct Action Type	72
4.2.1	Performance Comparison for Step Input and Square Wave Input	73
4.2.2	Simulation Result for Y-Thompson Spin Rate Data	93
4.3	Simulation Result for AFLC based on Hybrid Type	97
4.3.1	Performance Comparison for Step Input and Square Wave Input	97
4.3.2	Simulation Result for Y-Thompson Spin Rate Data	112
4.4	Performance Comparison between AFLC with PID Adaptation, AFLC with RLS Adaptation and FLCs	115

4.5	Simulation Result of AFLC with Cross Coupling Effect	130
4.5.1	Performance Comparison for Step Input and Square Wave Input	130
4.5.2	Simulation Result for Y-Thompson Spin Rate Data	139
4.6	Conclusion	140
CHAPTER 5 CONCLUSIONS AND FUTURE WORKS		
5.1	Conclusions	142
5.2	Future Works	146
	APPENDICES	148
	REFERENCES	151
	LIST OF PUBLICATIONS AND AWARD	159

LIST OF TABLES

NO.		PAGE
2.1	Classification of spacecraft by mass	10
3.1	The FAM Table	50
3.2	The FAM Table for $e(t) = NE$	55
3.3	The FAM Table for $e(t) = ZE$	55
3.4	The FAM Table for $e(t) = PO$	55
4.1	Step Response Analysis of direct action type controllers	76
4.2	The value MF shifting for direct action type controller	77
4.3	MSE for direct action type controllers with unity gain	80
4.4	MSE for direct action type controllers with varying gain	82
4.5	MSE for direct action type controllers with noise	85
4.6	MSE for direct action type controllers with delay	87
4.7	MSE for direct action type controllers with all operating condition	90
4.8	MSE for direct action type controllers with disturbance	93
4.9	MSE for AFPD, AFPI and AFPID controllers with Y-Thompson data	96
4.10	The step response Analysis of hybrid type controllers	99
4.11	MSE for hybrid type controllers with unity gain	100
4.12	MSE for hybrid type controllers with varying gain	103
4.13	MSE for hybrid type controllers with noise	105
4.14	MSE for hybrid type controllers with delay	107
4.15	MSE for hybrid type controllers with all operating conditions	109
4.16	MSE for hybrid type controllers with disturbance	111
4.17	Best controller performance analysis for InnoSAT Euler model based	112

	on time response	
4.18	Best controller performance analysis for InnoSAT Euler model based on Mean Square Error (MSE)	111
4.19	MSE for AFPIFPD and AFPFIFD controllers with Y-Thompson data	114
4.20	The step response Analysis of AFPIFPD, FPIFPD, AFWRLS and AFPID controller for Roll Axis	116
4.21	The step response Analysis of AFPIFPD, FPIFPD, AFWRLS and AFPID controller for Pitch Axis	117
4.22	The step response Analysis of AFPIFPD, FPIFPD, AFWRLS and AFPID controller for Yaw Axis	118
4.23	MSE for AFPIPD, FPIFPD, AFRLS and AFPID controller with unity gain	120
4.24	MSE for AFPIPD, FPIFPD, AFRLS and AFPID controllers with varying gain	120
4.25	MSE for AFPIPD, FPIFPD, AFRLS and AFPID controllers with noise	123
4.26	MSE for AFPIPD, FPIFPD, AFRLS and AFPID controllers with delay	123
4.27	MSE for AFPIPD, FPIFPD, AFRLS and AFPID controllers with all operating condition	126
4.28	MSE for AFPIPD, FPIFPD, AFRLS and AFPID controllers with disturbance	127
4.29	Best controller performance analysis for InnoSAT Euler model based on time	129
4.30	Best controller performance analysis for InnoSAT Euler model based	130

on Mean Square Error (MSE)

4.31 Time response for AFPIFPD in coupling plant effect

132

© This item is protected by original copyright

LIST OF FIGURES

NO.		PAGE
1.1	Earth satellite orbit	2
1.2	Attitude Determination and Control System	5
2.1	General satellite architecture	9
2.2	Standard CubeSAT Kit	11
2.3	InnoSAT External View	12
2.4	Satellite reference frame	14
2.5	Attitude Determination and Control System	15
2.6	Environmental disturbance torques	16
2.7	Spin stabilization satellite controls	18
2.8	Three-axis stabilization	19
2.9	Basic configuration of FLC	23
3.1	Workflow of an AFLC	40
3.2	Conventional Model Reference Adaptive System	42
3.3	Modified Model Reference Adaptive Control scheme	43
3.4	Root locus stability for MRAC parameter	44
3.5	Classification of Fuzzy PID controllers	45
3.6	Structure of Fuzzy PD controller	46
3.7	Membership function of error	48
3.8	Membership function for difference of error	49
3.9	Membership function of actuating signal	49
3.10	Root locus for InnoSAT plant	51
3.11	Root locus for stabilizer	51

3.12	Root locus for InnoSAT plant with stabilizer	52
3.13	Structure of Fuzzy PI controller	53
3.14	Membership function of total of error	53
3.15	Structure of Fuzzy PID controller	54
3.16	Structure of Fuzzy PI and Fuzzy PD controller	58
3.17	Structure of Fuzzy P + Fuzzy I + Fuzzy D controller	60
3.18	Block Diagram of Two Axes InnoSAT with Cross Coupling	66
3.19	Y-Thompson Spin for Roll Axis	68
3.20	Y-Thompson Spin for Pitch Axis	68
3.21	Y-Thompson Spin for Yaw Axis	69
4.1	Model Reference Output for Step Input Response	74
4.2	Step Response of Direct Action Type Controllers for InnoSAT Euler model	75
4.3	Shifting Membership Function	76
4.4	Model Reference Output for Square Wave Input	77
4.5	Performance Comparison for InnoSAT Euler model with unity gain	78
4.6	(a) is the zoom out of output response in Figure 4.5 and (b) is model following error of the zoom out response in (a)	79
4.7	Varying Gain	81
4.8	Performance Comparison for InnoSAT Euler model with varying gain	82
4.9	(a) is the zoom out of output response in Figure 4.8 and (b) is model following error of the zoom out response in (a)	83
4.10	Measurement noise at the plant output	84
4.11	Performance Comparison for InnoSAT Euler model with noise	85

4.12	(a) is the zoom out of output response in Figure 4.11 and (b) is model following error of the zoom out response in (a)	86
4.13	Performance Comparison for InnoSAT Euler model with delay	87
4.14	is the zoom out of output response in Figure 4.13 and (b) is model following error of the zoom out response in (a)	88
4.15	Performance Comparison for InnoSAT Euler model with all operating conditions	89
4.16	(a) is the zoom out of output response in Figure 4.15 and (b) is model following error of the zoom out response in (a)	90
4.17	Step disturbance of 5% between 300s and 600s	91
4.18	Performance Comparison for InnoSAT Euler model with disturbance	92
4.19	Performance Comparison for InnoSAT Euler model by using Y-Thomson spin rate data	95
4.20	(a) is the zoom out of output response in Figure 4.19 and (b) is model following error of the zoom out response in (a)	96
4.21	Step response of hybrid type controllers for InnoSAT Euler Model	98
4.22	Performance Comparison of hybrid type for InnoSAT Euler model with unity gain	100
4.23	(a) is the zoom out of output response in Figure 4.22 and (b) is model following error of the zoom out response in (a)	101
4.24	Performance Comparison of hybrid type controller for InnoSAT Euler model with varying gain	102
4.25	(a) is the zoom out of output response in Figure 4.24 and (b) is model following error of the zoom out response in (a)	103

4.26	Performance Comparison hybrid type for InnoSAT Euler model with noise	104
4.27	(a) is the zoom out of output response in Figure 4.26 and (b) is model following error of the zoom out response in (a)	105
4.28	Performance Comparison of hybrid type for InnoSAT Euler model with delay	106
4.29	(a) is the zoom out of output response in Figure 4.28 and (b) is model following error of the zoom out response in (a)	107
4.30	Performance Comparison of hybrid type for InnoSAT Euler model with all operating conditions	108
4.31	(a) is the zoom out of output response in Figure 4.30 and (b) is model following error of the zoom out response in (a)	109
4.32	Performance Comparison of hybrid type controller for InnoSAT Euler model with disturbance	110
4.33	Performance Comparison for InnoSAT Euler model by using Y-Thompson spin rate data	113
4.34	(a) is the zoom out of output response in Figure 4.33 and (b) is model following error of the zoom out response in (a)	114
4.35	Step response of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler Model	117
4.36	Shifting Membership Function with RLS	118
4.37	Performance of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler model with unity gain	119
4.38	Performance of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler model controllers with varying gain	121

4.39	Performance of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler model with noise	122
4.40	Performance of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler model with delay	124
4.41	Performance of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler model with all operating condition	125
4.42	Performance of AFPIPD, FPIFPD, AFRLS and AFPID controllers for InnoSAT Euler model with disturbance	127
4.43	Zoom out the output response in Figure 4.42	128
4.44	Step response of AFPIFPD controllers for cross coupling effect	131
4.45	Performance of AFPIFPD controllers for cross coupling effect with unity gain	133
4.46	Performance of AFPIFPD controller for cross coupling effect with varying gain	134
4.47	Performance of AFPIFPD controller for cross coupling effect with noise	135
4.48	Performance of AFPIFPD controller for cross coupling effect with delay	136
4.49	Performance of AFPIFPD controller for cross coupling effect with all operating conditions	137
4.50	Performance of AFPIFPD for cross coupling effect with disturbance	138
4.51	Simulation Result for cross coupling by using Y-Thompson spin rate data	139
4.52	The zoom out of output response in Figure 4.51	140

LIST OF ABBREVIATIONS

ACS	Attitude Control System
ADS	Attitude Determination System
ADCS	Attitude Determination and Control System
AFLC	Adaptive Fuzzy Logic Controller
AFPD	Adaptive Fuzzy Proportional Derivative
AFPFIFD	Adaptive Fuzzy Proportional + Fuzzy Integral + Fuzzy Derivative
AFPI	Adaptive Fuzzy Proportional Integral
AFPID	Adaptive Fuzzy Proportional Integral Derivative
AFPIFPD	Adaptive Fuzzy Proportional Integral + Fuzzy Proportional Derivative
AFRLS	Adaptive Fuzzy Recursive Least Square
AI	Artificial Intelligent
ANGKASA	National Aerospace Agency
ATSB	Astronautic Technology (M) Sdn. Bhd.
DA	Direct Action.
DISO	Double Input Single Output
ECI	Earth Coordinate Inertia
ES	Expert System
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Control
FPD	Fuzzy Proportional Derivative
FPFIFD	Fuzzy Proportional + Fuzzy Integral + Fuzzy Derivative
FPI	Fuzzy Proportional Integral
FPID	Fuzzy Proportional Integral Derivative

FPIFPD	Fuzzy Proportional Integral + Fuzzy Proportional Derivative
GPS	Global Positioning System
GUI	Graphical User Interface
HILS	Hardware-in-loop-simulation
HEO	High Earth Orbit
HI	High
InnoSAT	Innovative Satellite
IRAS	Infra- Red Astronomical Satellite
LEO	Low Earth Orbit
LO	Low
LQR	Linear Quadratic Regulator
MEO	Medium Earth Orbit
MF	Membership Function
MRAC	Model Reference Adaptive Control
MIMO	Multiple Input Multiple Output
MSE	Mean Square Error
NASA	National Aeronautics and Space Administration
NO	Normal
NE	Negative
OBC	On-Board Computer
PD	Proportional Derivative
PID	Proportional, Integral, Derivative
PFLC	Predictive Fuzzy Logic Control
P-POD	Poly-Pico Satellite Orbital Deployer
PO	Positive

RLS	Recursive Least Square
SISO	Single Input Single Output
SMC	Sliding Mode Control
SRM	Switched Reluctance Motor
UAV	Unmanned Aerial Vehicle
USM	Universiti Sains Malaysia
UTM	Universiti Teknologi Malaysia
UniMAP	Universiti Malaysia Perlis
UHF	Ultra High Frequency
UOD	Universe of Discourse
VHF	Very High Frequency
WRLS	Weighted Recursive Least Square
ZE	Zero

© This item is protected by original copyright

LIST OF SYMBOLS

x^*	defuzzified output
$\mu(x)$	degree of membership function
x	output variable
m	number of inputs
k	number of linguistic
r	radius of orbit
ϕ	Roll angle
θ	Pitch angle
ψ	Yaw angle
X	Roll axis
Y	Pitch axis
Z	Yaw axis
t	Time
$P(t)$	covariant matrix
$K(t)$	Kalman filter
$\varphi(t)$	information vector that consists of the controller inputs
$\lambda(t)$	forgetting factor
λ_0	initial forgetting factor
$\psi(t)$	gradient of the one step ahead predicted output
α	constant value between 100 and 10000
$r(t)$	reference input
$y_m(t)$	output of reference model
$y(t)$	plant output

$\varepsilon(t)$	prediction error
$e(t)$	error
$\Delta e(t)$	Derivative of error
a_m, b_m	Model reference parameters
$\hat{\theta}(t)$	Proportional, Integral and Derivative (PID) Error
$\hat{\Theta}(t)$	Vector of controller parameters
$u(t)$	Control signal from fuzzy controller
$\Sigma e(t)$	integral of error
$u_s(t)$	control signal from stabilizer
$u_d(t)$	constant disturbance torque
u_{pi}	output Fuzzy PI controller
u_{pd}	output Fuzzy PD controller
u_d	output Fuzzy D
u_p	output Fuzzy P
u_i	output Fuzzy I
T_o	orbital rate time of the InnoSAT
G or g	gravitational attraction at Earth's surface
R	radius of Earth
\mathbf{I}	Identity matrix
K_p	proportional gain
K_i	integral gain
K_d	derivative gain
$K_p(t)$	Varying gain

Pembangunan Pengawal Ubah Suai Kabur untuk Sistem Kawalan Sikap Satelit

ABSTRAK

Pembangunan dalam memajukan ruang angkasa merupakan suatu penanda aras baru dalam menentukan kecanggihan teknologi moden bagi sesebuah negara pada masa kini. Oleh sebab itu, sebagai sebuah negara yang membangun, Malaysia juga tidak mahu ketinggalan untuk menjadi salah satu negara yang terlibat dalam meneroka bidang teknologi satelit ini. Secara amnya, satelit akan menerima gangguan daripada pelbagai fenomena yang berlaku di angkasa. Fenomena ini boleh mengganggu kedudukan satelit pada bila-bila masa dan keadaan. Oleh itu, pengawalan orientasi dan penstabilan kedudukan satelit adalah perlu dengan menggunakan sistem kawalan sikap (ACS). Projek ini mencadangkan kawalan ubah suai samar sebagai ACS satelit Inovatif (InnoSAT). Objektif projek ini adalah untuk membandingkan masa tindak balas dan prestasi pengesanan antara struktur pengawal. Parameter wacana sejagat akan ditalakan secara dalam talian oleh mekanisme pelarasan yang merupakan satu kaedah yang serupa dengan ralat PID yang boleh mengurangkan ralat antara keluaran sebenar dan keluaran rujukan model. Tesis ini juga membentangkan Model Rujukan Kawalan Suai (MRAC) sebagai skim kawalan untuk mengawal sistem berubah dengan masa di mana spesifikasi prestasi diberi dari segi model rujukan. Semua pengawal telah diuji menggunakan sistem InnoSAT dengan memasukkan pelbagai keadaan operasi yang melibatkan gangguan, gandaan berubah, pengukuran hingar dan tunda masa. Secara keseluruhannya, kajian ini mencadangkan lima struktur pengawal untuk satelit ACS. Tiga struktur terdiri daripada Tindakan Langsung dan dua struktur daripada jenis Hibrid. Pada mulanya, pengawal jenis Tindakan Langsung seperti Pengawal Ubah Suai Kabur PD, Ubah Suai Kabur PI dan Ubah Suai Kabur PID digunakan. Walau bagaimanapun, prestasi pengawal ini sedikit merosot apabila pengawal diuji dengan data sebenar iaitu data Y-Thomson. Maka, struktur hibrid seperti Ubah Suai Kabur P + Kabur I + Kabur D dan Ubah Suai Kabur Selari PI + Kabur PD pengawal dicadangkan untuk mengatasi masalah tersebut. Sebagai perbandingan, pengawal yang mempunyai prestasi terbaik akan dibandingkan dengan pengawal lain seperti Pengawal Kabur dan Pengawal Ubah Suai dengan algoritma Pemberat Rekursi Kuasa Dua Terkecil. Keputusan simulasi menunjukkan bahawa semua pengawal yang dicadangkan telah mendapat prestasi yang baik dalam mengesan masukan rujukan. Kawalan Ubah Suai Samar menunjukkan persembahan yang terbaik dengan kebolehpayaan dalam mengawal satelit berbanding dengan kawalan samar. Oleh itu, ini membuktikan bahawa Ubah Suai Kabur PI + Kabur PD merupakan pengawal yang terbaik untuk aplikasi ini. Sumbangan projek ini adalah untuk membawa Malaysia terus ke peringkat antarabangsa yang lebih maju bukan sahaja dalam penyelidikan, malahan dapat membangunkan dan mereka bentuk sistem satelit sendiri.

Development of Adaptive Fuzzy Controller for Satellite Attitude Control System

ABSTRACT

Development of space is one of the main symbols of technological progress in the modern society. Therefore, as a developing country, Malaysia not left in becoming one of the countries involved in exploring the field of satellite technology. Generally, the satellite receives interference from various phenomena that occurred in space. These phenomena can disturb the satellite position at any time and condition. Thus, it is necessary to control the orientation and maintain the stability of satellite by the attitude control system (ACS). This project proposed an Adaptive Fuzzy controller for ACS of Innovative Satellite (InnoSAT) based on Direct Action and Hybrid type controller structure. The objective of this project is to compare the time response and tracking performance among the structures of controller. The parameters of universe of discourse are tuned on-line by adjustment mechanism which is an approach similar to a PID error that could minimize errors between actual and model reference output. This thesis also presents a Model References Adaptive Control (MRAC) as a control scheme in order to control time varying systems where the performance specifications are given in terms of reference model. All the controllers have been tested using InnoSAT system with some operating conditions such as disturbance, varying gain, measurement noise and time delay. In order to study new methods used in satellite attitude control, this thesis presents five structure of controllers. Three structures are from Direct Action type and two structures are from hybrid type. At first, Direct Action type controller such as Adaptive Fuzzy PD controller, Adaptive Fuzzy PI and Adaptive Fuzzy PID have been applied. However, the performances of these controllers are slightly degraded while the controllers are tested in real data which known as Y-Thomson data. Thus, hybrid structure such as Adaptive Fuzzy P + Fuzzy I + Fuzzy D and Adaptive Parallel Fuzzy PI + Fuzzy PD controllers are proposed to overcome the problem. To compare the performance with other controller, Fuzzy and Adaptive Fuzzy controllers with Weighted Recursive Least Square Algorithm is proposed. Simulation results show that all controllers that have been proposed have a good performance. Adaptive Fuzzy controller shows the best capability and stronger robustness from Fuzzy controller. Thus, the application of the Adaptive Fuzzy PI + Fuzzy PD controller is expected to be valuable. The contribution of this project is to bring this country for more advanced in satellite systems in future as well as for the international market.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Based on National Aeronautics and Space Administration (NASA), satellite is referred to as the moon, planet or machine that orbits a planet or a star. Therefore, satellite can be categorized into two types which are natural satellite and artificial satellite. Examples of natural satellite are earth and moon. This is because the Earth orbits the sun while the moon orbits the Earth. Artificial satellite is commonly defined as a machine that is launched into space and orbits the Earth atmosphere. Thousands of man-made satellites move in orbit with specific function which are mainly for television and radio broadcasting, communication such as internet and phone calls, weather forecasting, agricultural monitoring system, Global Positioning System (GPS) and many more.

Orbit is a gravitational curve path that functions as a track for satellite movement in space. Basically, every planet and satellite has their own orbit in order to prevent them from collision. The Earth atmosphere, artificial satellite will orbit at three different levels: Low Earth Orbit (LEO), Medium Earth Orbit (MEO) and High Earth Orbit (HEO); see Figure 1.1. Hence, different satellite orbits Earth at different heights as well as speeds and paths which depend on the characteristics and functions of the artificial satellite (Riebeek & Simmon, 2009). Satellites positioned at LEO consist of communication, military and observation satellites where the distance from the earth's surface is between 180 km to 2000 km. As for MEO, the height of the satellite positioned here is at approximately 2000

km to 35780 km above earth. This orbit is also known as polar orbit. Satellites positioned at this orbit are weather, observation and spy satellite. Last but not least, HEO is the further orbit which is 35780 km and above from earth's surface. Satellite positions here are space observation and weather observation satellite.

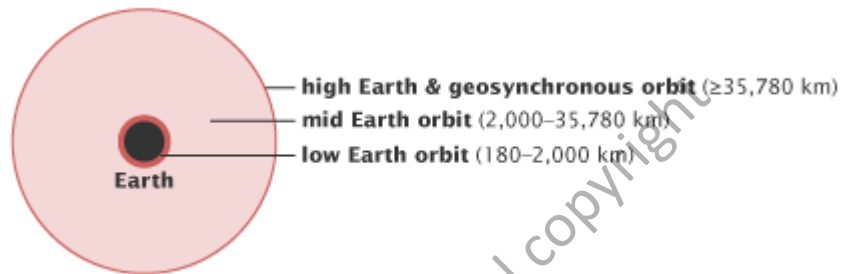


Figure 1.1: Earth satellite orbit (Riebeek & Simmon, 2009)

Generally, the Earth circles the sun in its orbit. Hence, the satellite design needs to move along with the Earth in order to fulfill its mission. This is achieved by hardware and software embedded in the satellite system. The system is required to continuously calibrate its instrumentation and optimize its control performance in the space for all time (Sidi, 2001). Advancement in technology has led to higher requirements on the performance of satellite control. Future satellite is expected to achieve highly accurate pointing position towards earth in the presence of large environmental disturbance.

1.2 Problem Statement

A satellite will orbit the Earth when its speed is balanced by the pull from the Earth's gravity. Without this balance, the satellite would fly in a straight line off into space